Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 144 (2016) 674 – 681

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Vibration Problems, ICOVP 2015

Improved Acoustic Energy Harvester Using Tapered Neck Helmholtz Resonator and Piezoelectric Cantilever Undergoing Concurrent Bending and Twisting

Minu A Pillai[a] and Ezhilarasi D[a]*

[a]*Department of Instrumentation and Control Engineering, National Institute of Technology, Tiruchirappalli-620015, Tamilnadu, India*

Abstract

This work seeks to put forward an approach to enhance the voltage generated by an acoustic based piezoelectric energy harvester. When a flexible triangular foil is attached perpendicular to the PVDF cantilever beam there is an increase in strain in the beam, also there is an increment in the acoustic pressure amplification rate of the Helmholtz resonator due to the dimensional modification of its neck. The integrated effects of these modifications of the harvester on the output voltage have been investigated. When sound incident on the surface of the neck of the resonator, an oscillatory pressure is produced in the cavity, which in turns vibrates the PVDF cantilever beam and voltage generates. By amending the structure of the PVDF cantilever with a polyester foil attached perpendicular to it, the cantilever is driven into concurrent bending and twisting by the cavity pressure and therefore makes a noteworthy increase in the output voltage

Peer-review under responsibility of the organizing committee of ICOVP 2015

Keywords: acoustic energy harvesting; Helmholtz resonator; tapered neck; unimorph cantilever beam; resonant frequency;bending and torsional vibration

1. Introduction

The rapid growth of consumer electronics is an intense trend today, which modernize the way we communicate and entertain ourselves. The huge deployment of these low power electronics has paved a great foundation for new

* Corresponding author. Tel.: +91-431-250-3350; fax: +91-431-250-0133.
E-mail address: ezhil@nitt.edu

Peer-review under responsibility of the organizing committee of ICOVP 2015
doi:10.1016/j.proeng.2016.05.065

mechanisms of converting unused available energy into usable (electrical) energy. The unharnessed energy from the surrounding environment have the benefit of being ample, pervasive and cause less environmental harm. The so called energy harvesting technology has therefore hit a tipping point providing energy security and stability in this era of energy crisis [1]. Advanced technical developments have sparked interest in the engineering community to develop more and more applications that utilize power from energy harvesting, thereby contributing to the realization of an infinite source of energy.

Acoustic energy harvesting is a relatively young subfield within energy harvesting due to the low power density of its sources, but it is increasingly hunted due to the ubiquitous nature of the source as well as the technological developments in the realization of truly autonomous MEMS devices and energy storage systems. With the global concern for energy and environmental issues, growing interests have been devoted to acoustic energy harvesting and it becomes a research frontier [1]. Low frequency noise is an inherent by-product of this technology, which is hardly investigated to explore the possibility of harvesting or to effectively control yet.

In reference [1] the authors have provided a detailed literature of acoustic based piezoelectric energy harvesting in macro and micro scales. There are many futuristic changes which scientists are trying to acquaint with both the resonators and transducer element to increase harnessed power. Earlier S K Tang proved that the smoother area change from the neck towards the cavity reduces the flow of resistance of the sound waves and hence increases the sound absorption capacity of the Helmholtz resonator [2]. Later Li et al. explored a piezo leaf where a PVDF cantilever is attached with a large triangular plastic leaf at its free end for wind energy harvesting [3, 4]. Making use of the above structural amendments, the proposed approach presents a compliant and economical technology which makes use of acoustic energy from ambient environment, with mutual applications in increased energy harvesting and environmental noise reduction.

The concept of attaching a flexible triangular structure perpendicular to the thin cantilever film to induce torsional deflection along with the lateral bending deflection when it is subjected to the increased pressure inside the tapered neck Helmholtz resonator cavity thereby increasing the output voltage forms the main axis of this work. Due to its wide use in real time acoustic applications, Helmholtz resonator is used to effectively transmit the sound energy to the transduction element without significant loss [5]. Although several transduction mechanisms exist for transformation of acoustic pressure oscillations into electric energy, piezoelectric transduction seems to be an appropriate mechanism due to its simplicity and stable performance [6].

2. Working Principle

Helmholtz resonator consists of a body to contain a volume of air and a neck in which a slug of air vibrates back and forth. The enclosed volume of air acts as a spring connected to the mass of the slug of air, and vibrates in an adiabatic fashion at a frequency dependent on the density, volume of the air, its molecular composition and the mass of the slug of air in the neck as shown in figure 1 [7,8].
For a resonator with negligible wall losses, the pressure amplification factor, G at its resonance frequency is the ratio of the acoustic pressure amplitude, p_c within the cavity to the external driving pressure amplitude, p_i of the incident sound wave and is given as [9]

$$G = \frac{P_c}{P_i} = \sqrt{V \frac{L^3}{S^3}} \quad (1)$$

Since the pressure amplification factor of the resonator is proportional to the dimensions of the neck, the tapering of the neck towards the cavity; i.e. the smoother area change from the neck towards the cavity will reduce the flow of resistance of the sound waves and will increase the sound absorption capacity of the Helmholtz resonator. The resonant frequency of the Helmholtz resonator with tapered neck is given by [2]

$$f = \frac{c}{2\pi}\sqrt{\frac{S}{LV} + \frac{m\pi r_i}{L}} \quad (2)$$